The physicochemical properties of flour based on indigenous Indonesian tubers produced by autoclaving-cooling cycling treatment

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ABSTRACT. The indigenous Indonesian tubers has a potency as a food ingredient. The autoclaving-cooling treatment could modify the physicochemical properties of flour from tubers to make it easier to use. This study was aimed to examine the physicochemical properties of flour based on indigenous Indonesian tubers produced by autoclaving-cooling cycling treatment. The native flour used in this study that came from small and medium enterprises in Yogyakarta consisting of cassava, taro, potato, sweet potato and yam flour. Native flour was processed through 1, 2, and 3 times of autoclaving-cooling . The experiment was conducted using a completely randomized design with 3 replications. The physicochemical properties observed i.e. pasting properties using rapid visco analizer; starch, amylose, sugar, resistant starch, starch digestibility, and dietary fiber content. The results showed that: 1) The addition of number of autoclaving-cooling cycle causes a significant increase in amylose, dietary fiber, resistant starch and sugar content, and also decrease in starch and starch digestibility content; 2) The pasting ability of starch from tuber flour was decrease with the addition of number of autoclaving-cooling cycling treatment. This condition was marked by a decrease in the value of peak, trough, and final viscosity; 3) Modified cassava flour has the highest value of viscosity profile compared to flour from other tubers; 4) The native cassava flour has the highest viscosity value compared to flour from other tubers; 5) Cassava flour which is treated through one autoclaving-cooling cycle has the highest retrogradation ability compared to other; 6) Flour modification still needs to be developed including with combining the physical treatment (autoclaving-cooling cycling) and biology treatment (sub-merged fermentation using commercial inoculum) to produce flour with a high content of amylose and resistant starch.

Keywords: indigenous indonesian tubers, autocalving-cooling cycling, flour modification, physicochemical properties, pasting properties

1. Introduction

Local tubers such as cassava, taro, sweet potato, yam, and potato were food stuff sources of carbohydrates that have a variation in starch content, a ratio of amylose and amylopectin, and dietary fiber content[1]. Flour is an intermediate product of tubers that could be used as a raw material in processed foods such as bakery products, noodles and others. The autoclaving cooling cycling treatment were applied to modify the functional and physicochemical properties of tuber flour, including the pasting and gelatinization profile, amylose, dietary fiber, and resistant starch. The modification make flour easier to be used as a food ingredient.

The autoclaving cooling cycling treatment on flour involve the gelatinization and retrogradation processes. During gelatinization, the linear structure of starch (amylose and amylopectin at the branching point) will be degraded to form structures with shorter chains and when retrogradation, recrystallization will occur at linear structure of starch through hydrogen bonds forming a complex double helix with low solubility and gelatinization properties[2,3]. The process of autoclaving (121ºC, 15 mnt) and cooling (4ºC, 24h) by 3 cycles was able to increase resistant starch (2.12% to 11.71%), amylose, and reducing sugars[4].

2. Material and Method

The native flour used in this study (cassava, taro, potato, sweet potato and yam flour) came from small and medium enterprises in Yogyakarta. The native flour was processed through 1, 2, and 3 times of autoclaving-cooling. The stages in the production of modified flour through autoclaving cooling cycling treatment shown in Figure 1.

The modified tuber flour was analyzed for starch and total sugar content by the anthrone method[5], amylose content by the iodine-binding assay[6], resistant starch[7], total dietary fiber[8], starch digestibility[9], pasting properties by using a Rapid Visco Analyzer from TecMaster Newport Scientific Pty. Ltd., Warriewood, Australia[10].

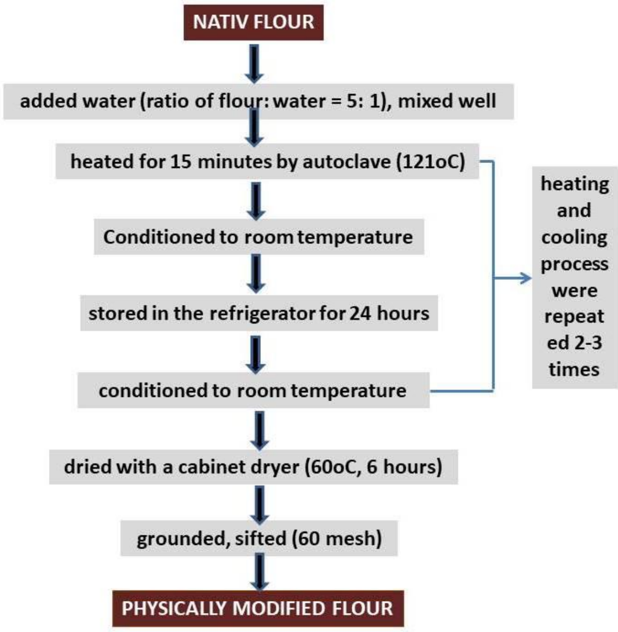

Figure 1. The stages of autoclaving-cooling cycling treatment of tuber flour

The experimental design used in this study was Randomize Complete Block Design. All treatments were repeated in a triplicate. Statistical data analysis employed software SPSS V.20 with One Way Anova and Univariate Analysis of Variance at significance level of 95% ($p<0.05$). Means difference was using Duncan's test.

3. Result and Discussion

3.1. Physicochemical properties

The different types of tubers have a different in the physicochemical properties. The autoclaving cooling cycling treatment caused the changes of physicochemical properties of flour. The results of this study (Table 1) showed that the type of tuber and the cycles number of autoclaving cooling had a significant effect ($p <0.05$) on the physicochemical properties of flour i.e. amylose, sugar, resistant starch, dietary fiber, and starch digestibility. The type of tuber had a significant effect ($p <0.05$) on starch content but not for the number of autoclaving cooling cycles. The native cassava flour has highest in starch content, then followed by native flour of yam, taro, potato and sweet potato. The native potato flour has highest in amylose content, then followed by native flour of taro, yam, sweet potato and cassava. The native sweet potato flour has highest in sugar content, then followed by native flour of cassava, taro, yam, and potato. The native potato flour has highest in resistant starch content, then followed by native flour of taro, yam, sweet potato, and cassava. The native yam flour has highest in dietary fiber content, then followed by native flour of sweet potato, taro, potato and cassava. The native cassava flour has highest in starch digestibility, then followed by native flour of sweet potato, yam, taro, and potato.

Table 1. The physicochemical properties of modified tuber flour

Type of flour	Time of cycle	Starch (%db)	Amylose (%db)	Sugar (%db)	RS (%db)*	DF (%db)**	SD (%db)***
Cassava	0	82.77±0.81[a]	7.94±0.08[h]	4.96±0.05[f]	2.21±0.02[h]	6.53±0.02[j]	78.1±0.77[a]
	1	81.67±0.73[a]	8.22±0.07[gh]	6.84±0.03[e]	7.19±0.03[d]	11.38±0.02[i]	74.44±0.54[c]
	2	80.91±0.79[a]	8.78±0.06[g]	7.97±0.02[de]	10.3±0.04[bc]	14.21±0.04[h]	72.29±0.49[d]
	3	80.35±0.63[a]	9.21±0.08[g]	8.86±0.04[d]	12.1±0.02[a]	16.48±0.03[fg]	70.52±0.38[e]
Taro	0	53.59±0.39[d]	17.97±0.11[d]	3.89±0.02[g]	3.24±0.01[fg]	16.31±0.02[fg]	56.82±0.51[f]
	1	52.27±0.44[d]	18.19±0.08[d]	5.05±0.04[f]	5.19±0.01[e]	18.69±0.04[e]	56.22±0.24[fg]
	2	51.63±0.28[de]	19.28±0.09[cd]	6.72±0.03[e]	6.75±0.03[de]	19.41±0.03[de]	55.42±0.19[g]
	3	50.84±0.35[e]	20.45±0.11[c]	7.13±0.05[e]	7.11±0.02[d]	20.22±0.15[cd]	53.9±0.27[h]
Sweet potato	0	45.65±0.33[f]	14.64±0.08[f]	14.14±0.06[c]	2.87±0.01[gh]	17.85±0.09[ef]	75.99±0.52[b]
	1	43.29±0.26[fg]	15.21±0.12[ef]	16.61±0.05[b]	4.84±0.02[ef]	19.67±0.07[cd]	75.49±0.26[b]
	2	42.62±0.32[g]	15.25±0.06[ef]	18.42±0.07[a]	5.39±0.03[e]	20.13±0.05[cd]	72.93±0.38[d]
	3	41.93±0.28[g]	15.45±0.13[ef]	19.98±0.06[a]	6.54±0.02[de]	21.87±0.03[c]	71.87±0.44[d]
Potato	0	53.21±0.26[d]	31.73±0.21[b]	2.98±0.01[g]	4.01±0.03[f]	15.7±0.04[g]	56.09±0.17[fg]
	1	51.85±0.41[de]	31.89±0.17[ab]	3.02±0.01[g]	5.38±0.01[e]	17.05±0.02[f]	52.94±0.39[i]
	2	50.31±0.19[e]	33.41±0.13[a]	3.11±0.01[g]	6.95±0.02[d]	18.43±0.04[e]	49.55±0.28[j]
	3	49.88±0.26[e]	33.62±0.09[a]	3.85±0.01[fg]	8.02±0.02[cd]	19.84±0.03[cd]	47.94±0.16[k]
Yam	0	72.86±0.55[b]	16.16±0.05[e]	2.99±0.01[g]	3.05±0.01[gh]	19.34±0.02[de]	57.56±0.37[f]
	1	71.43±0.57[b]	16.45±0.04[de]	3.14±0.02[g]	6.25±0.03[de]	21.63±0.06[c]	54.11±0.26[gh]
	2	69.21±0.66[bc]	17.09±0.09[d]	3.58±0.02[fg]	8.71±0.02[c]	24.31±0.04[b]	50.05±0.43[j]
	3	68.81±0.58[c]	17.84±0.06[d]	3.68±0.01[fg]	10.9±0.03[b]	26.71±0.07[a]	46.53±0.29[l]

The different content of starch, amylose, sugar, dietary fiber, resistant starch, and starch digestibility from the same type of tuber were found from studies that have been conducted by several previous researchers. This were due to the differences in the plant varieties studied, the place of plants growth, the age of plants harvest, and the method of analysis conducted[11,12]. Cassava, taro, sweet potato and yam flour have total dietary fiber content of 3% db, 12% db, 7% db, and 11% db, respectively[13]. Taro flour derived from tubers grown in Queensland Australia had starch, amylose, resistant starch and digestibility content of 80.95% wb, 5.59% wb, 35.19% wb, 50.42%, respectively. For yam flour were 78.83% wb, 14.60% wb, 22.48% wb, 45.72%, respectively. For sweet potato flour were 65.05% wb, 18.12% wb, 0.97% wb, 98.74%, respectively[14]. The content of starch, amylose, resistant starch, and digestibility of taro flour that came from Tulung Agung, East Java, Indonesia were 65.4% wb, 17.3% wb, 10.8% wb, 74%, respectively. For yam flour were 70.2% wb, 33.1% wb, 11.9% wb, 82.6%, respectively. For sweet potatoes were 64% wb, 42.7% wb, 4.7% wb, 33.3%, respectively. For cassava flour were 77.4% wb, 13.1% wb, 19.3% wb, 78.9%, respectively[15].

The autoclaving-cooling cycling treatment cause a significant increase ($P<0.05$) in amylose, sugar, resistant starch, and dietary fiber content; while starch digestibility decreased (Table 1). Through 3 cycles of autoclaving-cooling, the percentage of starch content decreasing on cassava, taro, sweet potato, potato, and yam flour were 2.92%, 5.13%, 8.15%, 6.26%, and 5.56%, respectively; the increase in amylose content, i.e. 15.99%, 13.80%, 5.53%, 5.96%, 10.40%, respectively; the increase in sugar content, i.e. 78.63%, 83.29%, 41.30%, 29.19%, 23.08%, respectively; the increase in dieary fiber, i.e. 152.37%, 23.97%, 22.52%, 26.37% and 38.11%, respectively; the increase in starch digestibility i.e. 9.71%, 5.14%, 5.42%, 14.53%, and 19.16%, respectively. Through 3 cycles of autoclaving-cooling, the increase in resistant starch on cassava, taro, sweet potatoes, potatoes, and yam flour were 4.47, 1.19, 1.27, 1.00, and 2.57 folds, respectively.

Starch is a mainly factor on the physicochemical, rheological, and textural behaviour of the modified flour. Starches that consisting of amylose and amylopectin play an important role in the viscosity properties descripted in the paste and gelatinization profile[16,17,18]. The changes on starch properties also affect on the other physicochemical characteristics of flour, such as resistant starch, starch digestibility, dietary fiber and sugar content. The autoclaving-cooling treatment causes starch degradation due to the unbinded of hydrogen bonds of amylose molecules in linear structures and amylopectin in branching structures. Starch degradation causes an increase in starch damage which was reflected by a tendency to decrease in starch content in line with the increasing of the number of autoclaving-cooling cycles. The similar results were shown in the autoclaving-cooling treatment on taro chips[19] and cassava starch[20,21].

The unbinded of hydrogen bonds in starch molecules causes an increase in amylose content due to the linearization of the branching structure of amylopectin. Starch degradation forms shorter, lower molecular weight polymers, partly measured as a sugar component[20,22]. This condition causes an increase in total sugar content in line with the increasing number of autoclaving-cooling cycles. An increase in reducing sugar content in line with the increasing number of autoclaving cooling cycles[19].

An increase of resistant starch content in line with the addition of the number of autoclaving-cooling cycles due to an increase in retrogradated amylose when the flour was cooled. During retrogradation, the linear chains of amylose and amylopectin in their branches were re-binded with hydrogen bonds to form an complex aggregate that consisting of double helix structures[20,21,23]. The similar results were shown in the study of wheat and corn starch[24], taro flour[19], arrowroot starch[25,26], banana flour[27,28].

Resistant starch is starch that cannot be digested by digestive enzymes[29]. Resistant starch was classified as insoluble dietary fiber[20]. So that, an increase in resistant starch content along with the increase in the number of autoclaving-cooling cycles causes an increase in dietary fiber content. This result was in line with those reported about banana flour research[27,28]. The retrogradation process which causes the increase in resistant starch and dietary fiber content also results in a decrease in starch digestibility content. These results were in line with the study about banana flour[21] and arrowroot starch[26]. The flour from tubers that resulting from physical modification through the autoclaving-cooling cycles have potency as a source of a prebiotic substance and functional ingredient for diabetics because it has a high content of resistant starch and dietary fiber, and also has a low content of starch digestibility. This product was also thought to has a low glycemic index, but the quantitatively must be proven through the further research.

3.2. Pasting properties

The native cassava flour has the highest viscosity values both peak viscosity, trough viscosity, and final viscosity, and then followed by potato starch, taro flour, gembili flour, and sweet potato flour (Table 2). Peak viscosity shows the viscosity when the starch granules were maximum swollen when heated[30]. Trough viscosity is the viscosity when the gelatinized starch granules were maintained at high temperatures (95^{o}C). Final viscosity shows the viscosity of the paste cooled at 50^{o}C. Starch with large granule size shows a high peak viscosity value because it is easier to absorb large amounts of water during gelatinization before the granules finally break, and otherwise with starches that have small granule sizes[31]. The size of tuber starch granules is very dependent on the variety. Some researchers report that the diameter size of cassava and sweet potato starch granules was 5-25 μm[32], potatoes was <110 μm[33], yam was 3-22 μm[34], and taro was 7μm[35]. The results of the gelatinization profile analysis of several researchers for the same type of tuber, as in this study were varied. The peak viscosity, trought viscosity, setback viscosity and final viscosity for taro flour were 265.8cP, 250.6cP, 236.8cP, and 487.4cP, respectively. Sweet potato were 34.5cP , 11.1cP, 1.8cP and 12.9cP, respectively[14]. The peak viscosity, setback viscosity and final viscosity for yam flour were 113.58RVU, 30.50RVU, and 141.58RVU, respectively[36]. The peak viscosity, trough viscosity and final viscosity for cassava flour with different varieties were 3100-4325m-Pa-s, 2580-2640m-Pa-s, and 3080-3210m-Pa-s, respectively[37].

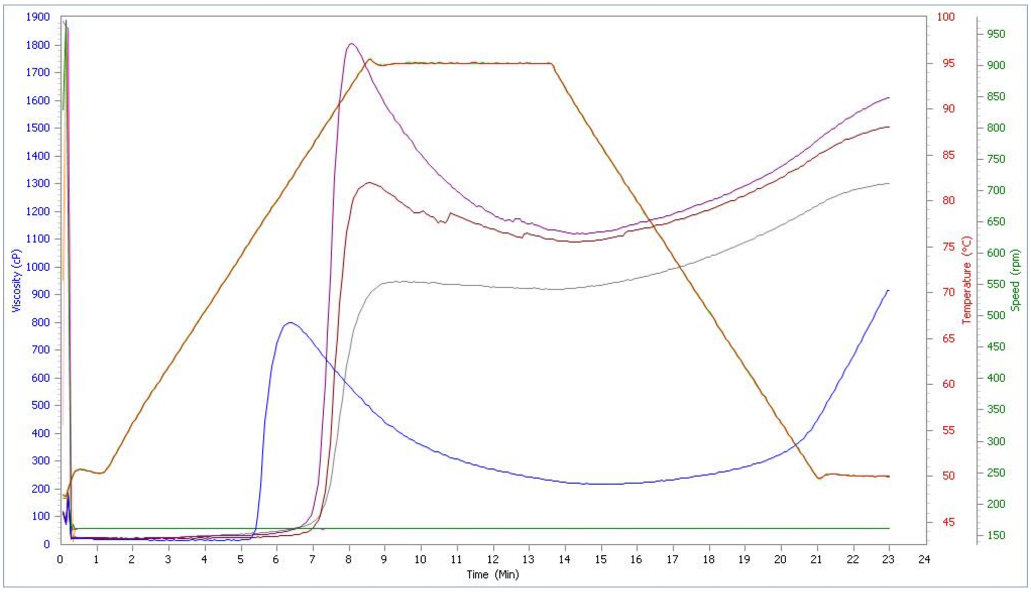

Fig.2. Pasting properties of modified tuber flour

The viscosity profile of starch paste was obtained from gelatinized starch. The viscosity profile was determined by the substance of the swollen starch and material coming out of the granules during gelatinization[18]. Starch, especially amylose, plays a dominant role in the properties of starch paste, gelatinization, and retrogradation[16,17]. The gelatinization process begins with the imbibition of water into the starch granules in a reversible manner. The increase in gelatinization temperature causes the amount of water bound to the granules to grow irreversibly, the starch granules swell, and will break if the amount of water bound has reached its maximum limit. Formation of starch paste will change the crystalline area of starch into amorphous[38]. The results showed that the autoclaving-cooling treatment caused a significant ($P<0.05$) decrease in viscosity both peak, trough, and final viscosity (Figure 2). The decrease in viscosity was due to the reduced ability of starch granules to gelatinize due to increased content of resistant starch which was characterized by increasing aggregate complexes composed of double helical structures. The heat that occurs during the autoclaving process causes many starch molecules to degrade so that the gelatinization ability decreases. The results of this study were in line with the results of previous studies i.e. the process of autoclaving-cooling of taro flour[19] and cassava starch[20,21]. An increase in amylose content in line with the increase in the number of autoclaving cooling cycles causes the swelling ability of starch granules decreases due to the formation of strong crystalline aggregates[39]. Decrease in starch content and high content of dietary fiber contribute to a decrease in peak viscosity values[40]. The autoclaving-cooling cycling treatment causes the value of final viscosity was higher than peak viscosity. The high final viscosity compared to peak viscosity shows a high degree of association between starch-water and its high ability to re-crystallize, and at the same time shows a high resistance to pressure and stirring during cooking and cooling. Final viscosity is strongly influenced by the ability of starch granules to be retrogradated[41].

Table 2. The viscosity profile of modified tuber flour

Type of flour	Time of cycle	Viscosity (cP)		
		Peak	Trough	Final
Cassava	0	5746±39.09 a	2372±18.88 c	3688±21.76 b
	1	3647±20.21 b	2407±19.05 b	4211±23.89 a
	2	1905±15.07 d	1605±14.21 d	2819±19.78 c
	3	1319±10.09 e	1314±10.56 e	1949±15.11 d
Taro	0	2324±15.15 c	1577±12.87 de	2543±16.34 cd
	1	992±7.03 g	915±7.54 f	1509±11.09 e
	2	231±3.11 i	230±3.89 i	338±5.32 h
	3	204±2.99 i	204±3.01 i	322±4.27 h
Sweet potato	0	1181±9.89 f	925±7.44 f	1478±11.09 e
	1	597±4.76 h	595±3.96 h	789±4.98 f
	2	106±1.11 j	105±1.14 jk	170±2.76 i
	3	57±0.43 lm	57±0.41 kl	81±0.55 jk
Potato	0	3615±24.15 b	2561±19.88 a	4512±28.84 a
	1	170±2.21 j	168±2.78 j	295±3.67 h
	2	66±1.98 lm	65±1.96 kl	98±0.56 j
	3	45±1.32 m	45±1.05 l	62±0.31 k
Yam	0	1288±9.98 ef	736±5.54 g	1425±11.04 e
	1	235±3.78 i	232±3.94 i	510±3.79 g
	2	126±2.07 j	124±2.16 jk	260±2.98 hi
	3	99±0.89 k	98±0.93 k	190±2.02 i

The one-time autoclaving-cooling process on cassava flour produced a different viscosity profile compared to other treatments. In this treatment, there was an increase in trough and final viscosity. The increasing of trough viscosity shown the resistancy of flour in the high temperature cooking. The high final viscosity value indicates the ability of starch granules to retrograde, ie the formation of strong bonds between amylose molecules or between amylose and amylopectin in their branching structures through hydrogen bonds[12].

Conclusion

The results showed that: 1) The addition of number of autoclaving-cooling cycle causes a significant increase in amylose, dietary fiber, resistant starch and sugar content, and also decrease in starch and starch digestibility content; 2) The pasting ability of starch from tuber flour was decrease with the addition of number of autoclaving-cooling cycling treatment. This condition was marked by a decrease in the value of peak, trough, and final viscosity; 3) Modified cassava flour has the highest value of viscosity profile compared to flour from other tubers; 4) The native cassava flour has the highest viscosity value compared to flour from other tubers; 5) Cassava flour which is treated through one autoclaving-cooling cycle has the highest retrogradation ability compared to other; 6) Flour modification still needs to be developed including with combining the physical treatment (autoclaving-cooling cycling) and biology treatment (sub-merged fermentation using commercial inoculum) to produce flour with a high content of amylose and resistant starch.

Acknowledgment
Acknowledgments were given to the Ministry of Research, Technology, and Higher Education of The Republic of Indonesia for the research funding provided through the grant of "Penelitian Unggulan".

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The physicochemical properties of flour based on indigenous Indonesian tubers produced by autoclaving-cooling cycling treatment

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2st International Conference on Multidisciplinary Approaches for Sustainable Rural Development (ICMA-SURE); Purwokerto, 19 November 2018





BACKGROUND

- **The indigenous Indonesian tubers such as cassava, taro, sweet potato, yam, and potato are source of carbohydrates.**
- **It have a potency as food ingredient, while have a limitation : the variation in starch and dietary fiber content, and ratio of amylose-amylopectin**
- **The previous research has shown that flour modification from tubers (such as taro) through controlled fermentation with commercial inoculums containing lactic acid bacteria, molds and yeasts (such as Bimo CF) could increase amylose content, final viscosity, and flour cohesiveness. It is potential to be used as filler on products processed at low temperature such as ice cream (Astuti, et al., 2017)**





BACKGROUND

The limitations of flour produced by biological modification through fermentation were has a high solubility , viscosity , and starch digestibility

Physical modification through heating cooling cycling treatment could modify the physicochemical properties of flour from tubers to make it easier to use and increase the functional properties of flour or starch.

The results of previous studies indicated that canna starch modified by heating and cooling treatment (2x) could be used for functional biscuits. production The product has high content of dietaty fiber and resistant starch (7.3 and 2.8%), and low in starch digestibility (36.7%) (Astuti et al., 2010)

OBJECTIVES

This study was aimed to :

examine the physicochemical properties of flour based on indigenous Indonesian tubers produced by autoclaving-cooling cycling treatment.



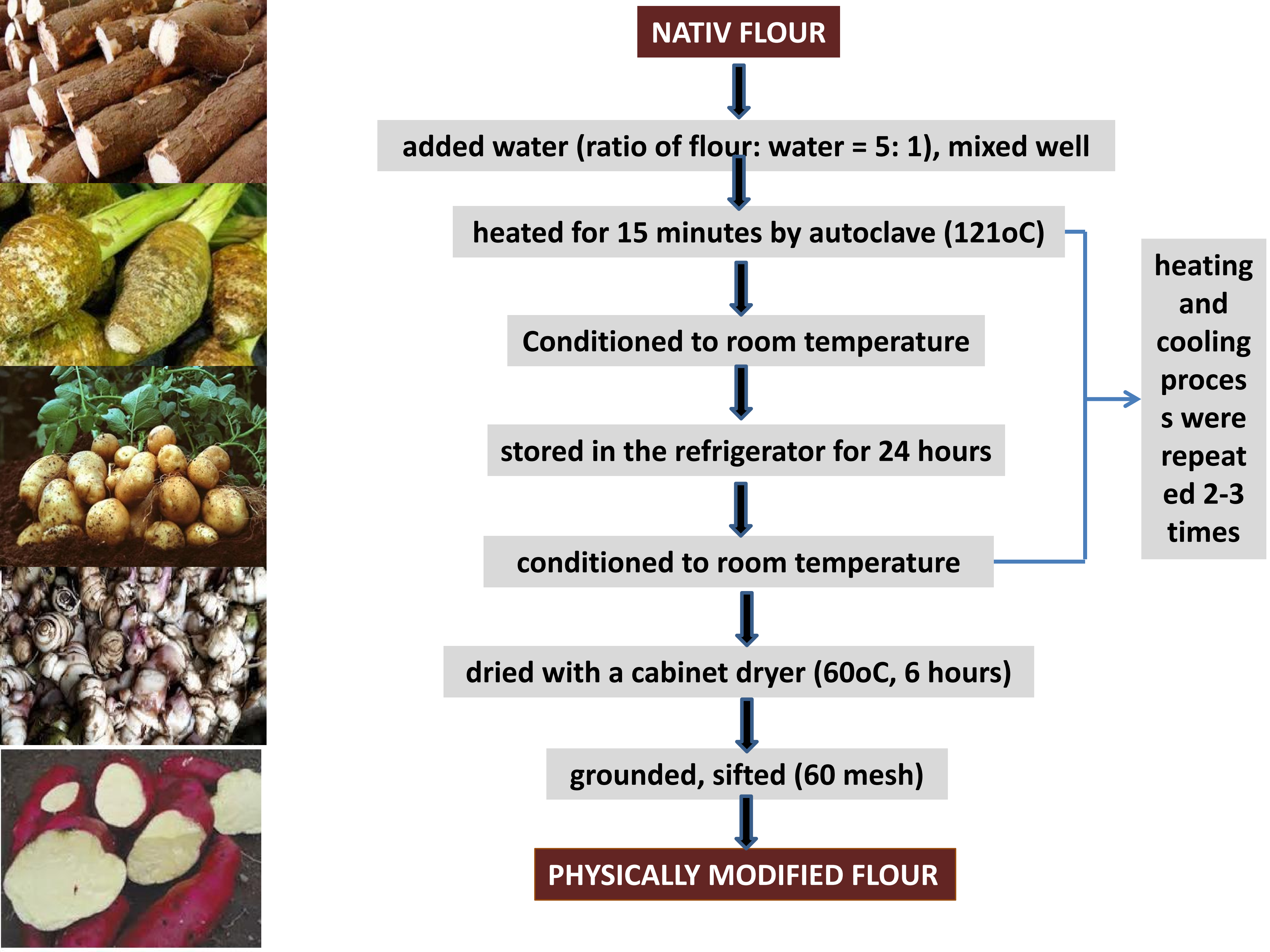


MATERIAL AND METHODS

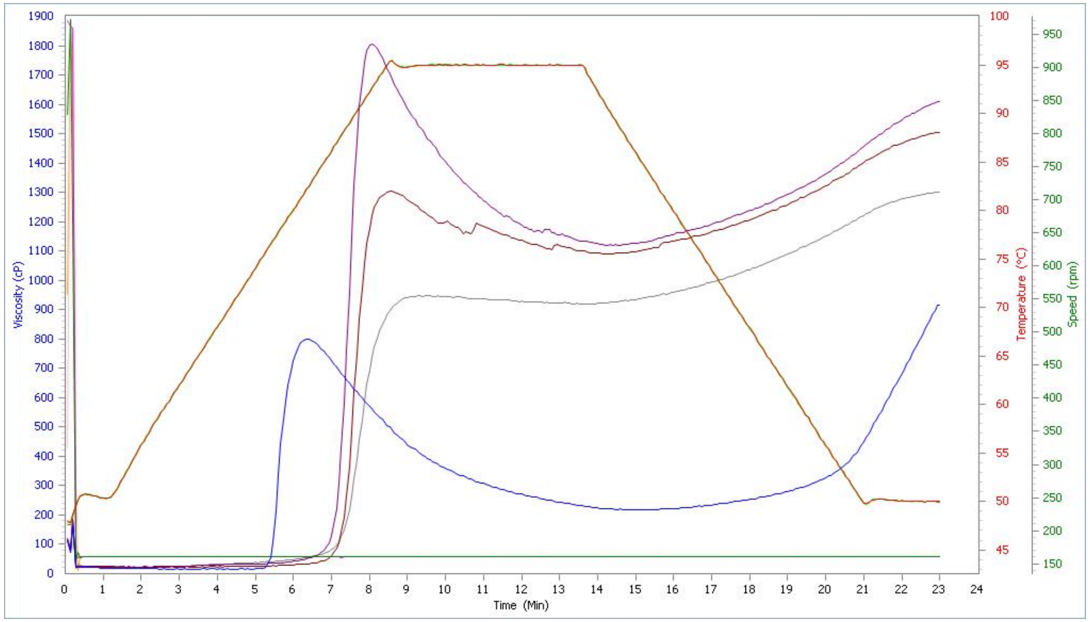
1. The native flour used in this study that came from small and medium enterprises in Yogyakarta consisting of cassava, taro, potato, sweet potato and yam flour.
2. Native flour was processed through 1, 2, and 3 times of autoclaving-cooling .
3. Experimental design used in this study was Randomize Complete Block Design. All treatments were repeated in a triplicate. Statistical data analysis employed software SPSS V.20 with One Way Anova and Univariate Analysis of Variance at significance level of 95% ($p<0.05$). Means difference was using Duncan’s test
4. The physicochemical properties observed i.e. pasting properties using rapid visco analizer; water, starch, amylose, sugar, starch digestibility, dietary fiber, and resistant starch content.



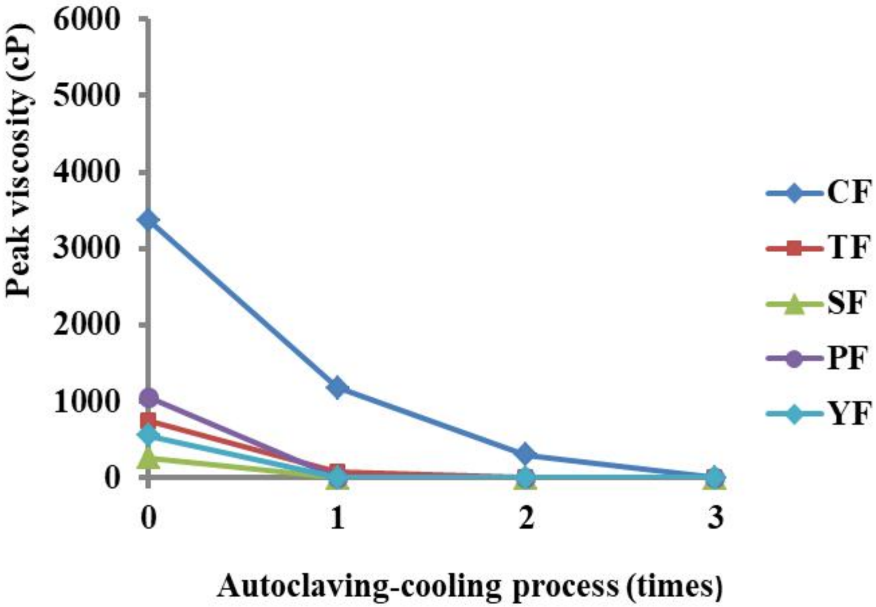


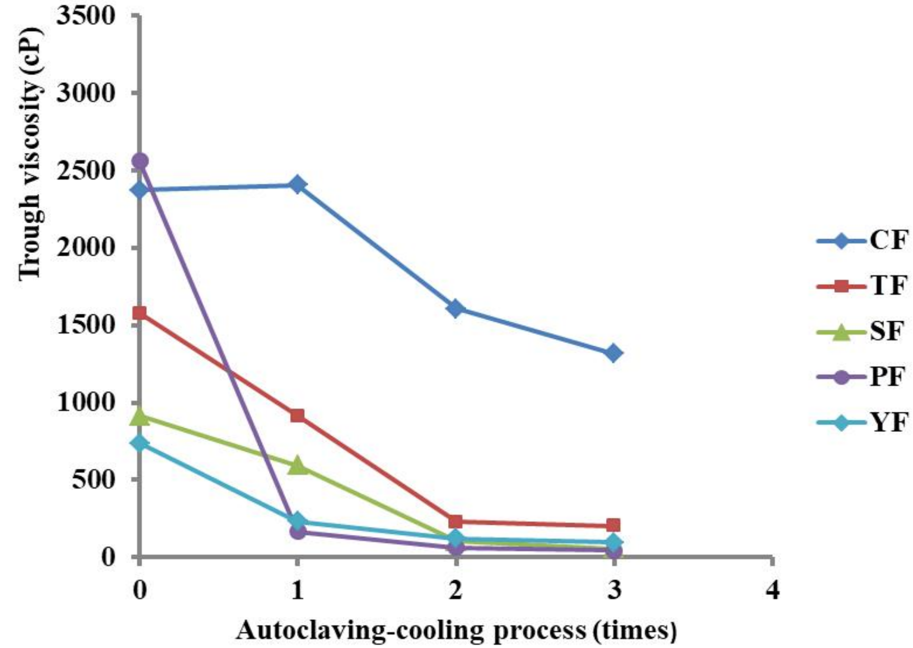

NATIV FLOUR
added water (ratio of flour: water = 5: 1), mixed well
heated for 15 minutes by autoclave (121oC)
Conditioned to room temperature
stored in the refrigerator for 24 hours
conditioned to room temperature
heating and cooling proces s were repeat ed 2-3 times
dried with a cabinet dryer (60oC, 6 hours)
grounded, sifted (60 mesh)
PHYSICALLY MODIFIED FLOUR

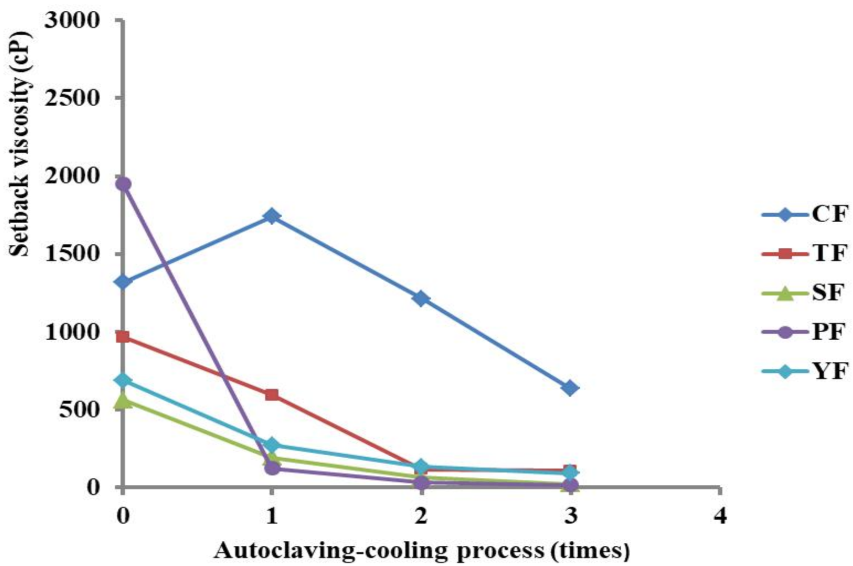
RESULTS : PASTING PROPERTIES

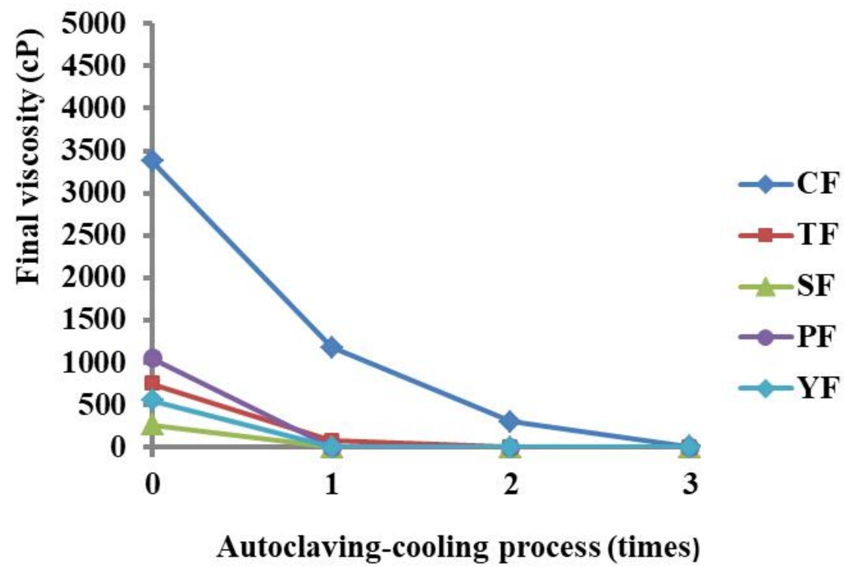


The pasting ability of starch from tuber flour was decrease with repeated autoclaving-cooling treatment. This condition was marked by a decrease in the value of peak, trough, setback and Final viscosity



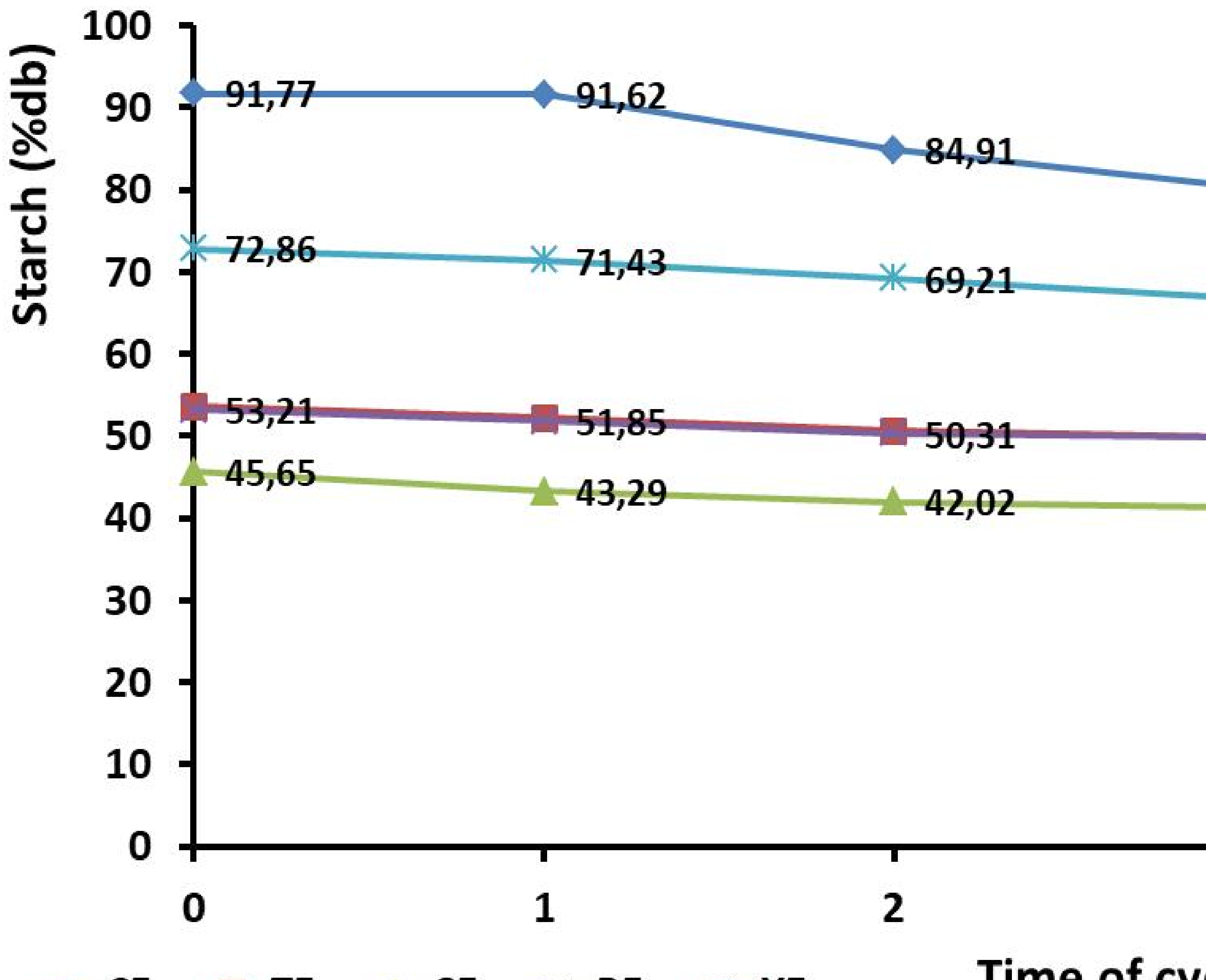






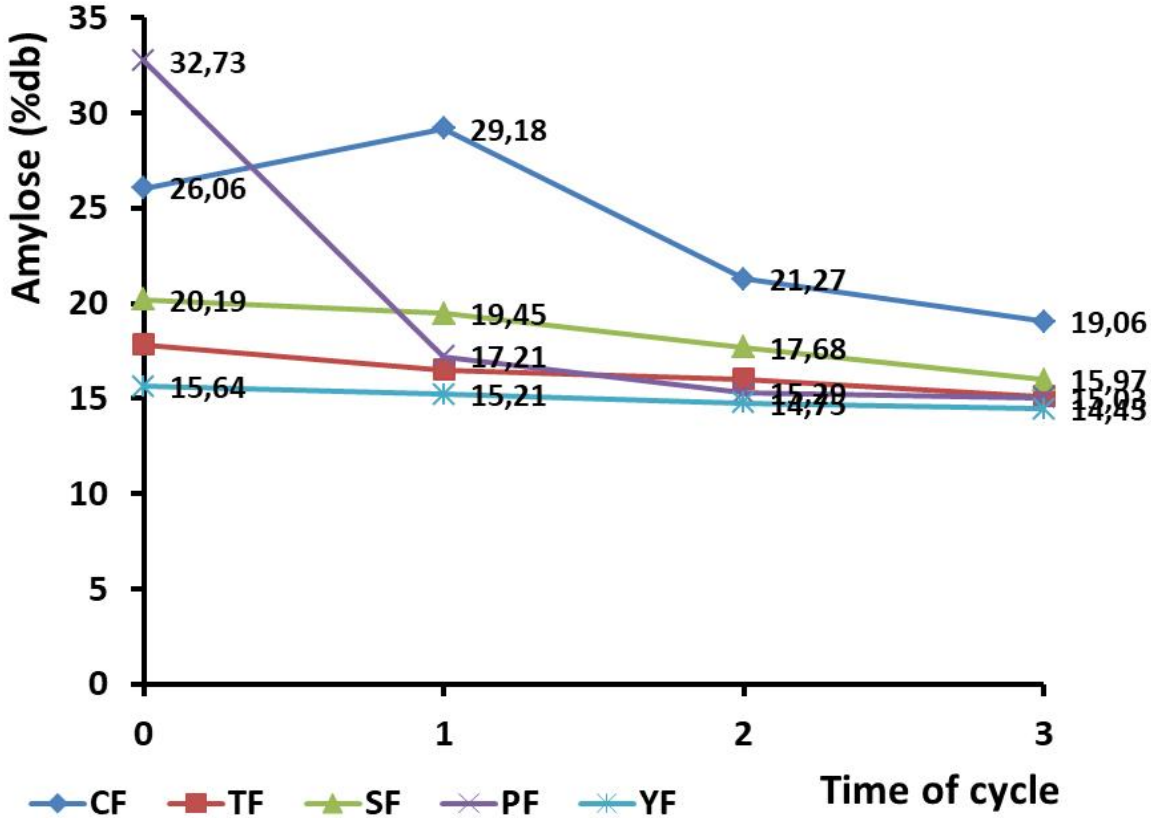
Cassava flour has the highest value of viscosity profile compared to flour from others

STARCH PROFILE



The ad

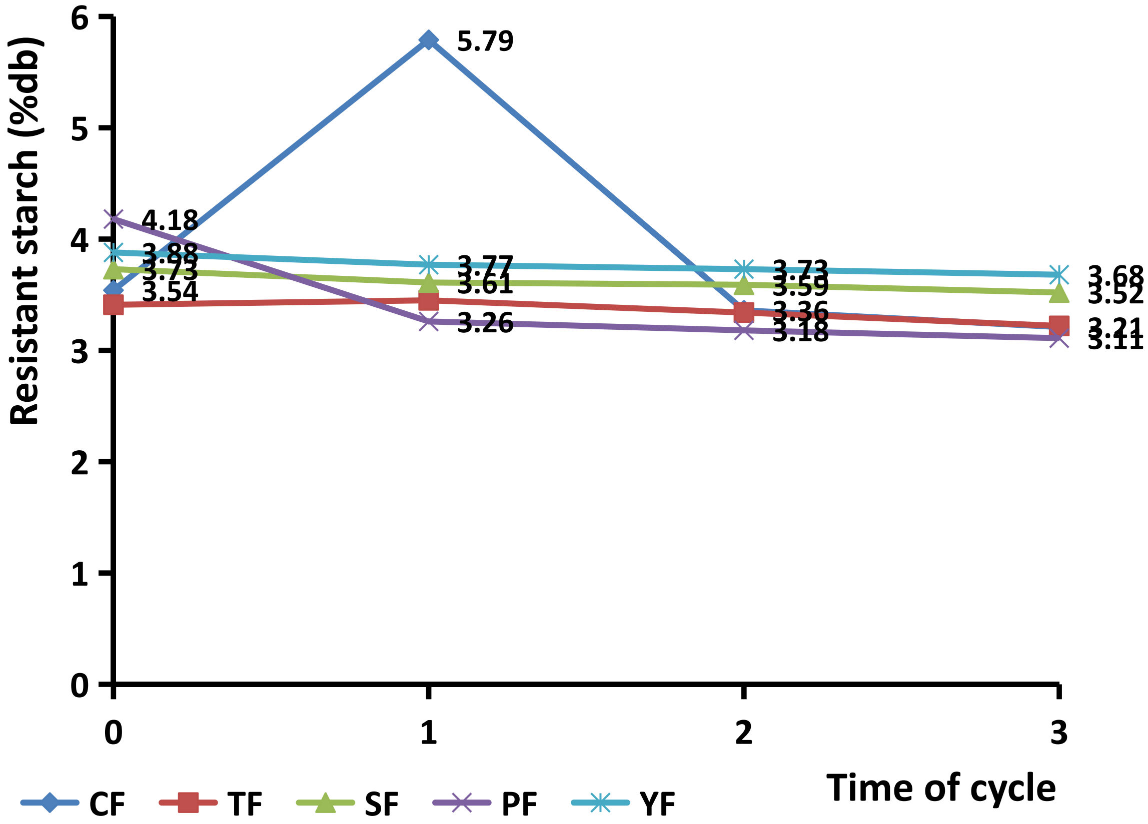
AMYLOSE PROFILE



CF=CASSAVA FLOUR; TF=TARO FLOUR; SF=SWET POTATO FLOUR; PF=POTATO FLOUR; YF=YAM FLOUR

The addition of the number of heating cooling cycling caused a decrease in amylose content, significantly (p<0.05)

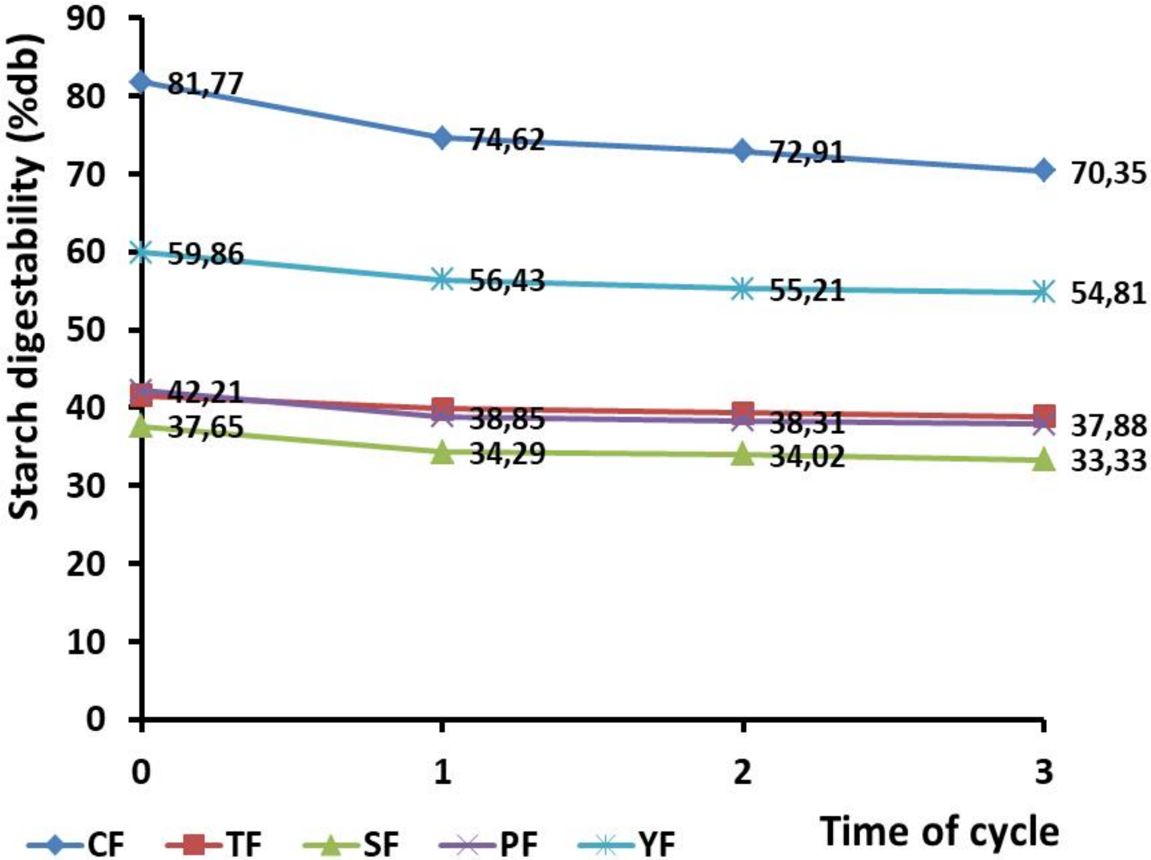
RESISTANT STARCH PROFILE



CF=CASSAVA FLOUR; TF=TARO FLOUR; SF=SWET POTATO FLOUR; PF=POTATO FLOUR; YF=YAM FLOUR

The addition of the number of heating coolilng cycling caused slightly decrease in resistant starch content

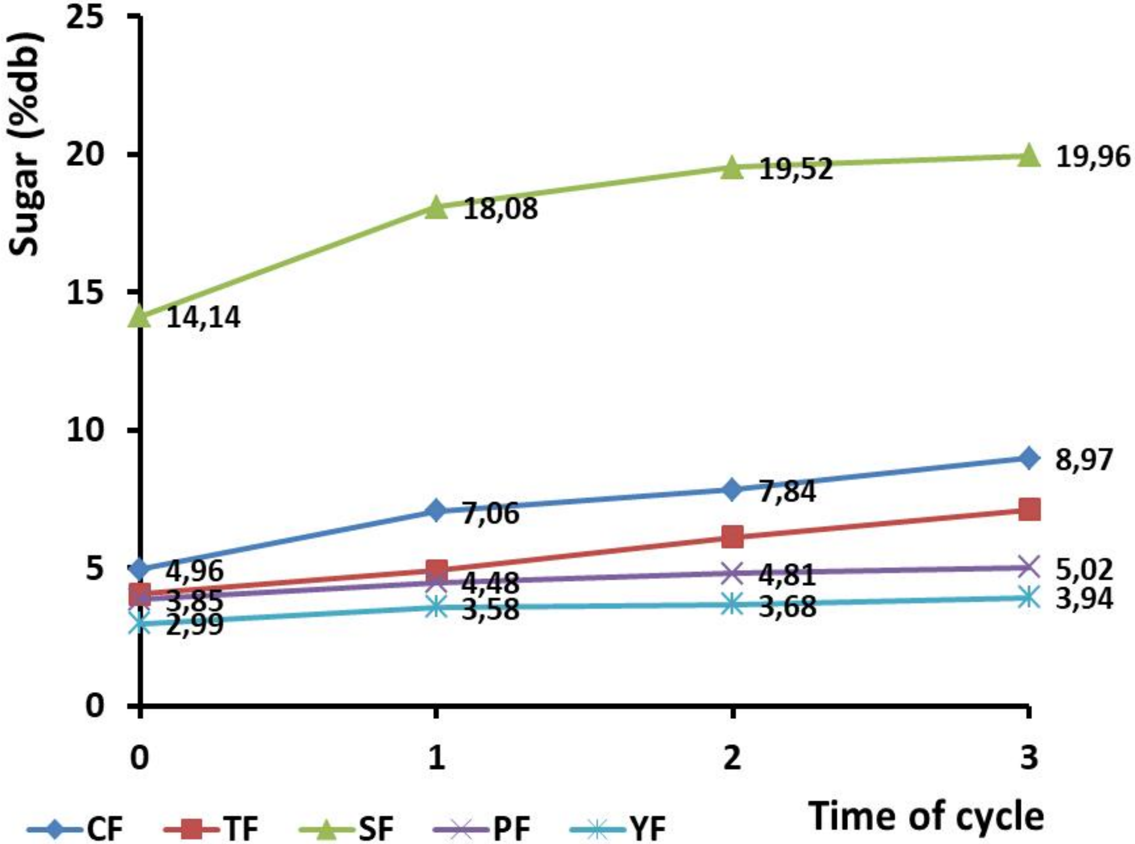
STARCH DIGESTABILITY PROFILE



CF=CASSAVA FLOUR; TF=TARO FLOUR; SF=SWET POTATO FLOUR; PF=POTATO FLOUR; YF=YAM FLOUR

The addition of the number of heating cooling cycling caused a decrease in starch digestability content, significantly (p<0.05)

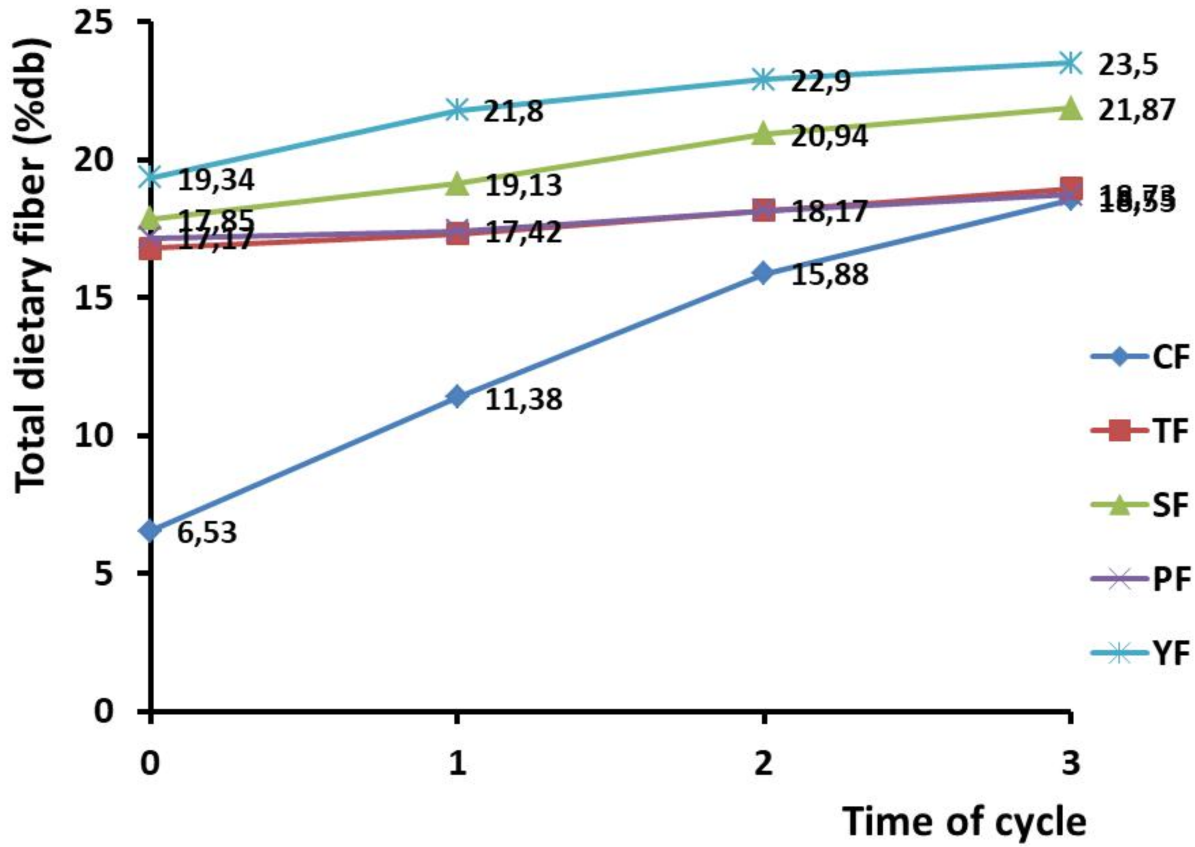
SUGAR PROFILE



CF=CASSAVA FLOUR; TF=TARO FLOUR; SF=SWET POTATO FLOUR; PF=POTATO FLOUR; YF=YAM FLOUR

The addition of the number of heating cooling cycling caused an increase in sugar content, significantly ($p<0.05$)

TOTAL DIETARY FIBER PROFILE



CF=CASSAVA FLOUR; TF=TARO FLOUR; SF=SWET POTATO FLOUR; PF=POTATO FLOUR; YF=YAM FLOUR

The addition of the number of heating cooling cycling caused an increase in total dietary fiber content, significantly ($p<0.05$)

DISCUSSION

1. Generally, high temperature on autoclaving treatment was be expected to cause hydrolyzed starch to become oligosaccharide molecules with smaller molecular weights than starch. It caused decrease in starch, amylose, and starch digestibility content and increase in resistant starch and dietary fiber content
2. Further hydrolysis of starch will produce low molecular weight molecules that causing an increase in total sugar content





CONCLUSION

1. Only cassava flour was appropriate to be treated through autoclaving-cooling cycling (1x) to increase in amylose, resistant starch, dietary fiber, and decrease in starch digestibility.
2. For other nativ flours were appropriate to be treated through heat moisture treatment. It done by mixing flour at a ratio of flour: water = 5: 1 then heating it for several hours at 100oC
3. Flour modification still needs to be developed including with combining the physical treatment (autoclaving-cooling cycling) and biology treatment (sub-merged fermentation using commercial inoculum) to produce flour with a high content of amylose and resistant starch.





THANK YOU FOR FUNDING THAT GIVEN BY THE MINISTRY OF RESEARCH AND HIGHER EDUCATION RI THROUGH THE RESEARCH GRANT 2019 (RISET UNGGULAN TERAPAN)





14

15

Taro

Potato

Sweet potato


K
S1
S2
S3
K
Ganyong
S1
Ganyong
S2
Ganyong
S3
Ganyong


CEPAT DINGIN
KAPASITAS BESAR
HEMAT LISTRIK